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Quantifying Telecoil Performance: Understanding Historical and Current ANSI Standards

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ABSTRACT

Methods for telecoil performance measurement have advanced from the relatively primitive physics lab procedure specified in the 1976 and 1986 American National Standards Institute hearing aid standards to the simulated telephone tests in the 1996 standard. Parallel advances in defining a hearing aid compatible telephone receiver as well as new telecoil testing methods had to occur for the 1996 tests to become possible. The new tests allow more accurate assessment of telecoil parameters and better estimation of expected real-life performance in telecoil mode.

KEYWORDS: Telecoil, telephone simulator, ANSI S3.22–1996, SPLITS, STS, TMFS

Learning Outcomes: As a result of this activity, the reader will understand the principles of hearing aid telecoil testing prescribed in the 1996 American National Standards Institute standard and the progression of technology that led to the standard.

THE FIRST AMERICAN NATIONAL STANDARDS INSTITUTE STANDARD

Until 1976, to describe the performance of hearing aids in the United States, one used the Hearing Industries Association (HIA) Standard.[1] This was a voluntary agreement by the hearing aid industry, with gain and output measured at 500, 1000, and 2000 Hz (the HIA average). It had no provision for measuring distortion, did not incorporate any tolerances, and did not even mention the telecoil. It was not legally binding and was basically a fairly loose gentlemen's agreement.

The 1976 American National Standards Institute (ANSI) hearing aid standard (S3.22–1976)[2] changed all that. It triggered major changes in the hearing aid field. Although it was ostensibly a labeling standard, regulating the

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technical information that was to accompany every hearing aid, its effects went much further. The HIA standard had been voluntary, but the new standard was based on federal law and legally binding. It specified new measurement procedures and allowable tolerances for the results of those measurements. For the first time, we had a document specifying electroacoustic performance that applied to every hearing aid sold in the United States. Henceforth, every hearing aid had to be accompanied by written data that included the specified measurements, and the hearing aid had to meet the data within the specified tolerances. The standard applied to the hearing aid industry as well as the dispensers, and a U.S. government agency, the Food and Drug Administration (FDA), was watching in the background to make sure the industry obeyed the outlined requirements. FDA inspectors visited manufacturers, checking on test procedures. The inspectors could (and sometimes did) apply sanctions to nonconforming manufacturers. Big Brother was watching.

The ANSI Working Group S3-48 for Hearing Aids, which wrote the new standard, included engineers from most hearing aid companies, plus representatives from the dispenser and audiological communities. This group put the standard together in the unheard of short time (for an ANSI standard) of 1 year. For this achievement, a great deal of credit goes to the knowledgeable and gentlemanly guidance of its chairman Sam Lybarger. Heavy pressure from the FDA was admittedly another factor.

In retrospect, there is no question that the new standard forced the hearing aid industry to improve its products and pushed the dispenser community toward better knowledge of the product they were fitting. With the clout of FDA ever-present in the background, manufacturers not only had to subject every hearing aid to a standardized battery of tests before it left the factory, they also had to make sure the hearing aid met the specifications for that model. The dispenser was required to provide a printed performance chart to the client. The tolerance limits in the standard were reasonable enough. In contrast, the old HIA standard, with no tolerance limits, essentially left the variation from hearing aid to hearing aid subject to the internal rules of each manufacturer. Those were only too often subject to a certain amount of flexibility affected by the customer's demand for immediate shipment, or the desire for a good shipping month.

A number of new measurement procedures were introduced in the ANSI standard, including measurements of distortion, saturation sound pressure level, and telecoil sensitivity. The new procedures not only forced the industry to improve its processes but also gave the dispenser more and better information. Let us examine the new method for testing telecoil performance, starting with the basics.

SERENDIPITY IN 1947

In 1947, Sam Lybarger at RadioEar Corp. described a new body-worn hearing aid, the Permo-Magnetic Radioear,[3] which featured "a new direct inductive pickup for telephone and radio use." Lybarger had discovered that the then-common Western Electric-Bell Laboratories telephone receiver, the U1, had a signal leakage field that could be picked up with another coil (this became the telecoil), amplified, and used to listen to the telephone, free of surrounding acoustic noises. He received a U.S. patent for this invention.

The U1 receiver leakage field that the telecoil picked up is actually undesirable magnetic spillage, an indication of inefficiency of the receiver magnetic structure. This receiver was made in enormous quantities, over 90 million by the time production ceased in 1981, and in most areas of the country it was in effect the default. However, it should be noted that the so-called independent telephone companies (e.g., GTE, Automatic Electric) never did have telephones that were compatible with telecoils, and the service areas dominated by these companies (mostly in the south) were notorious for complaints of poor telecoil performance.

THE ELECTROMAGNETIC FIELD

The electrical current carrying the speech signal in virtually every telephone flows through a coil of some kind. (A few telephones with ceramic-

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driven receivers have been made. On those, a separate coil provides the required magnetic field.) The current in the coil generates a magnetic field, which vibrates a diaphragm, moving air and resulting in an audible signal, mostly speech. Not all of the magnetic field does the useful work of moving the diaphragm. Some escapes outside the telephone and can be picked up by a telecoil. The strength of the field is measured in current per wire length, or amperes per meter. A milliampere, mA (0.001 ampere), per meter is a more convenient measure for practical measurements.

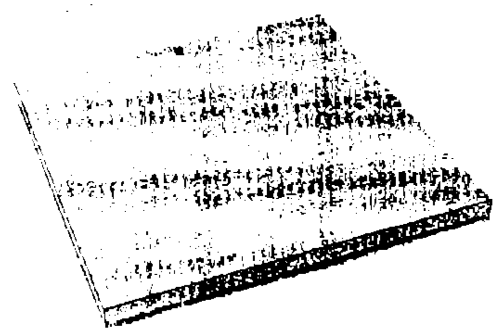

Figure 1 Telecoil test coil (16 × 16 × 3/4") for 1976–1986 ANSI Standard. (Courtesy of Frye Electronics Inc.)

THE ANSI S3.22-1976 TELECOIL TEST

The telecoil test section of the 1976 standard specified a 1 kHz electromagnetic field with a field strength of 10 mA/m. The hearing aid on a 2-cc coupler was placed in the center of the field and oriented for maximum sound pressure level (SPL) output. The example given for generating the field was for a coil 1 m in diameter, with 10 turns of copper wire around the periphery. The first coil made in our laboratory at Telex Communications followed the example and was large and cumbersome, made of three-quarter-inch plywood, with a hole about a foot diameter in the center for the hearing aid and 2-cc coupler. It was by no means a real-life test and was in fact more reminiscent of a basic physics laboratory experiment, but a big step forward from no test at all in the preceding HIA standard. Later, the simpler method of wrapping an appropriate coil around the Bruel & Kjaer test box became commonplace. This was a do-it-yourself project, as Bruel & Kjaer never did provide an official version. In any version of the coil, one had to make sure that the magnetic field in the measurement space had the specified field density of 10 mA/m, but that was a fairly simple procedure, requiring only basic measurement instruments and a few calculations. Eventually, commercial equipment makers such as Frye Electronics and Etymonic Research entered the field, producing gear to measure compliance with ANSI 1976. Their equipment included coils of quite reasonable size to measure telecoil sensitivity. (See Fig. 1.)

The choice of the specified 10 mA/m field strength had been made with inadequate information and under time pressure. This selected standard field strength turned out to be quite a bit lower than the field strength of a typical hearing aid compatible telephone, which is about 78 mA/m axial, 45 mA/m radial. We did not know this at the time. Even so, the standard served its purpose until more was learned about compatible telephones. Neither the test coil nor the test method bore much resemblance to an actual telephone. Thus the measuring procedure could not answer the basic question "How well does a particular hearing aid work in telecoil mode?" Nevertheless, a relative comparison of telecoil sensitivity among different hearing aid models was now possible. Because in 1976 there was no agreement yet on what the field strength of a hearing aid compatible telephone was, the resolution to the basic question had to await moves by the telephone industry.

THE TELEPHONE INDUSTRY AND THE HEARING AID COMPATIBLE TELEPHONE

The telephone industry (and particularly the Bell System) through the years has been receptive to the needs of the hearing-impaired public. An example of that receptiveness is the Bell System retrofitting, at considerable expense, all public coin telephones to be hearing aid compatible, starting in 1974. Why a large percentage of coin phones at that time were not compatible in the first place was a simple oversight, in which a giant industry was unaware of the needs of a relatively small segment of the public. An even more glaring example of this oversight is evident in the introduction of the new Bell System receiver to replace the U1, first introduced in the Slimline telephone in the late 1960s.[4] It was smaller, less expensive to produce, used fewer strategic materials, and was more efficient, but it was useless with a telecoil because it had a very weak stray field.

DEFINING THE HEARING AID COMPATIBLE TELEPHONE

The Slimline situation finally woke up the telephone industry to the importance of telecoils to hearing aid users. Around the same time period, the hearing aid industry had learned the value of cooperating on technical standards for the greater good of all, albeit under pressure from the FDA. Engineers from both industries started working together in the late 1970s as a joint committee (the author was co-chair), determining the methods of measuring the stray electromagnetic field (which had been up to now of no concern to the telephone industry) and testing a number of telephone receivers at various laboratories. After several years of work, the standard was written around the performance of the well-accepted and ubiquitous Bell System U1 receiver.[5] This became the Electronics Industry Association (EIA) Standard RS-504 of 1983, titled "Telephone Receiver Hearing Aid Compatibility," and with minor modifications it survives to this day.[6]

The minimum electromagnetic field strength of a hearing aid compatible telephone receiver in the EIA 504 standard was specified as −22 dB axial field, −27 dB radial, both re 1 A/m at 1 kHz. Those correspond to 78 and 45 mA/m, respectively. (The average of axial and radial fields is −25 dB; the significance of this number will be discussed further in the section on the practical meaning of the telephone standard.) These figures were the averaged result of measuring a number of U1 receivers at several laboratories. In addition, details of the field shape, frequency response, and associated circuitry were defined. Note that the axial field is 9.6 dB and the radial 4.6 dB higher than the 10 mA/m of the 1976 and 1987 ANSI standards.[2,7] One might ask, "Was this field adequate for hearing aids?" Actually, it was a case of taking a receiver that was out there by the millions and considered usable with telecoils, and deeming this to be the standard. There was no discussion of whether it was good enough or whether we in the hearing aid industry could expect more. We took what we could get and were glad to get it. The tiny and politically weak hearing aid industry had no chance of pressuring for more from the giant telephone industry. All this changed with Americans with Disabilities Act of 1992, but that was to be many years in the future.

MARGINAL ADEQUACY OF THE U1 RECEIVER MAGNETIC FIELD

Although the magnetic field of the U1 receiver and the resulting EIA standard were deemed hearing aid compatible and were the best available at the time, they were really just barely adequate and no more. As stated previously, it was the best the hearing aid industry could get without getting into a fight with the telephone industry that we could not possibly win. To achieve the desirable goal of a hearing aid being as loud in telecoil mode as in microphone mode, the hearing aid's amplifier gain had to be so high that the aid would be close to instability (motorboating). (The motorboating sound is a low-frequency buzz, resembling a small boat motor.) The cause is magnetic coupling from the hearing aid receiver back to the wiring and the telecoil, similar in principle to the acoustic feedback whistle that is the bane of many a hearing aid fitting. Adequate telecoil performance was thus just barely possible, but with considerable difficulty. It was a particularly tough problem in custom in-the-ear hearing aids, which were by then, in the late 1970s, beginning to dominate the market. Some manufacturers incorporated special telecoil preamplifiers, which helped, but required additional space, always a scarce commodity in in-the-ear hearing aids.

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TELECOIL WITH PREAMPLIFIER: A UNIVERSAL SOLUTION

The problem was not really solved until 1992, when a major supplier of telecoils, Tibbets Industries Inc., introduced a telecoil with a very small built-in preamplifier, the Model PA-3. Using a custom integrated circuit, it was not much bigger than a plain telecoil, although understandably it was more costly. Combining the preamplifier and coil into one package greatly reduced the magnetic field pickup due to wiring and allowed higher usable telecoil gain with much better stability. (See Fig. 2.)

IMPROVING THE ANSI STANDARD: PROGRESS OVER THE YEARS

Considering the time and regulatory pressures behind the 1976 standard, with the FDA pushing the industry hard to create, evaluate, and finish a brand new standard in the record time of 1 year, it was understandable that areas of improvements would be left for the future. A more realistic telecoil measurement was needed, but it required the creation and acceptance by the telephone industry of criteria for a hearing aid compatible telephone receiver. The 1983 EIA 504 Hearing Aid Compatible Telephone Standard[6] defined these criteria and made the subsequent development of better telecoil test methods possible.

Figure 2 Self-contained amplified telecoil, Tibbets Model PA-3. (Courtesy of Tibbets Industries Inc.)

The 1987 ANSI hearing aid standard[7] revised the 1976 version[2] and improved it, but the author recalls no attempts by the ANSI S3–48 committee to improve the telecoil measurement method. One could speculate that the main use of telecoils occurred in behind-the-ear aids, which had declined in market share to around 20% by that time. Another likely factor is that through the years, the telecoil has never occupied center stage in hearing aid technology, nor has there been a strong demand from the dispensing community for improvements in telecoil technology or information. The telecoil part of the ANSI standard at that time was primitive enough: a measurement at just one frequency (1 kHz), with the hearing aid moved around until maximum output was reached. Be that as it may, it took until the 1996 ANSI Standard[8] to develop a new, more realistic test method.

1996 ANSI STANDARD AND TELECOIL TESTING

In the 1996 ANSI Standard (ANSI S3.22–1996)[8] the telecoil measurement was changed to a method very similar to actual telephone use and thus could be directly related to the performance of the hearing aid on a real-life telephone. The prime mover behind that effort was Bill Cole of Etymonic Design Inc. in Canada, and his contribution should be recognized. See Table 1 for a comparison of 1976/86 and 1996 ANSI telephone measurements.

SIMULATED TELECOIL SENSITIVITY

The new method is logical and straightforward but introduces a number of new concepts and corresponding acronyms. The end goal is to define and measure the simulated telecoil sensitivity (STS). A test coil is defined in the standard and called, logically enough, a telephone magnetic field simulator (TMFS). The TMFS generates a 31.6 mA/m magnetic field (which is −30 dB re 1 A/m), with the intent of approximating the output of a typical hearing aid compatible telephone.

Table 1 Comparison of 1976/87 and 1996 ANSI Telephone Measurements

	ANSI 1976/87	ANSI 1996
Field strength	10 mA/m	31.6 mA/m
Frequency	1000 Hz	1000, 1600, 2500 Hz
Measuring coil size	Not specified	Simulated telephone
HA location	Move around for maximum reading	Simulated telephone use

The sample TMFS coil described in the standard is cylindrical, about 3 inches in diameter. The coils produced by test equipment manufacturers have taken different forms, similar in size to a telephone and producing the required field strength. Examples from two manufacturers are shown in Figures 3 and 4. The TMFS and the hearing aid are placed against each other, with the hearing aid connected to a 2-cc coupler.

The SPL output of the hearing aid into the 2-cc coupler is measured at three frequencies (1000, 1600, and 2500 Hz) and averaged. This SPL is named sound pressure level for inductive telephone simulator, or SPLITS (the "inductive" is obviously necessary because English does not lend itself to pronouncing five consonants in a row). Other acronyms combine the familiar with SPLITS, such as HFA-SPLITS (for high frequency average-SPLITs) and SPA-SPLITS (for special purpose average-SPLITS). In addition, a frequency response curve in telecoil mode is introduced in the standard.

Figure 3 Testing the simulated telephone sensitivity of an in-the-ear hearing aid with a TMFS (Etymotic Model RE740). The hearing aid is placed against the TMFS. (Courtesy of Etymotic Design Inc.)

THE SIMULATED TELEPHONE SENSITIVITY FORMULA

Basically, simulated telephone sensitivity (STS) is the difference between output SPL resulting from a 60-dB acoustic input and the output SPL resulting from an inductive input via the telephone simulator: STS = SPLITS − RTG + 60+, where SPLITS is the SPL with the telecoil simulator (telecoil mode), and RTG (reference test gain) plus 60 is the SPL with 60-dB acoustic input (microphone mode).

WHAT DOES STS MEAN?

The STS procedure compares the acoustic output, with 60-dB acoustic input, with the acoustic output from a simulated telephone. If the two numbers are equal,. STS is zero. Stated differently, if STS is zero, telecoil output is equal to acoustic output with 60-db input (both averaged over three frequencies). If STS is negative, say −2 or −3, it means the output in telephone mode is 2 or 3 dB lower than the output resulting from 60-dB SPL input to the microphone. A positive number means some reserve is available for telephone mode, which is desirable. For example: RTG = 43 dB; HFA SPLITS = 103 dB SPL; STS = 103 − (43 + 60) = 0.

For satisfactory real-life telephone use, should STS be zero, or less than zero, or more than zero? The author is not aware of clinical or other studies addressing this issue. However, it is noteworthy that the British, Swedish, and Australian governments specify that SPL of the telecoil with 31.6 mA/m field and microphone mode with 60-dB input be within ±5 dB of each other. This is exactly the same thing as saying that STS (in the U.S. standard) shall

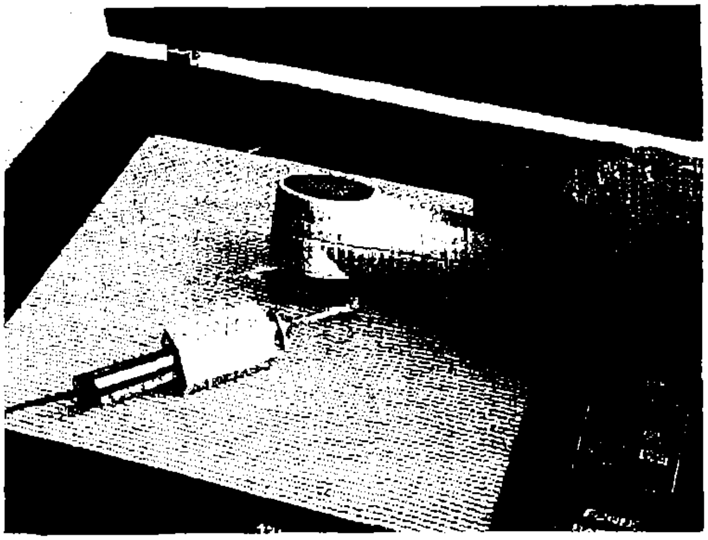

Figure 4 Testing the STS of a behind-the-ear hearing aid with a TMFS ("Telewand®"). The TMFS is placed against the hearing aid. (Courtesy of Frye Electronics Inc.)

be within ±5 dB of zero. The clear implication is that STS = 0 is desirable.

Examining the numbers defining STS and TMFS lead to the same conclusion. (The algebraically challenged may skip this paragraph.) Assume a hearing aid with STS = 0 (i.e., the SPL output is the same with 60-dB SPL acoustic input or −30 dB re 1 A/m magnetic field input). Recall that average speech level at 3 feet is about 65 dB SPL, 5 dB more than the standard. The magnetic field of an EIA 504 compatible telephone is −25 dB re 1A/m, also 5 dB more than the TMFS. Therefore, this hearing aid is equally loud with average speech and with a compatible telephone, surely a desirable condition.

SPLITS CURVE

Another measurement defined by the 1996 standard is the SPLITS curve. As the name implies, it is the response curve of the hearing aid with the telephone simulator providing the input. This curve provides useful information to the dispenser, assuring that the telecoil response is appropriate. In the not-too-distant past, the author has run across hearing aids with a telecoil curve that peaked sharply at 1 kHz, providing a nice high number under the older standards but sounding unpleasant, as well as undesirable, by any audiological criterion. (See Fig. 5.)

SUMMARY

The ANSI S3.22–1996 Hearing Aid Standard[6] introduced new procedures for measuring telecoil performance. These procedures simulate real-life telecoil performance much more closely than the 1976 and 1986 standards did. The foundation for these improved procedures was laid with parallel advances in hearing aid and telephone technologies and standards.

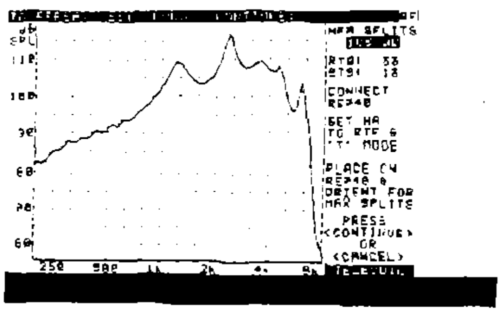

Figure 5 Response curve of a telecoil with telephone simulator input (the SPLITS curve). (Courtesy of Etymonic Design Inc.)

The test methods mandated by the 1996 ANSI Standard[8] should result in more accurately testing telecoil performance and may contribute toward greater acceptance of this sometimes neglected hearing aid feature.

ABBREVIATIONS

ANSI	American National Standards Institute
EIA	Electronic Industries Association
FDA	Food and Drug Administration
HFA	High Frequency Average (at 1000, 1600, 2500 Hz)
HIA	Hearing Industries Association
RTG	Reference Test Gain (at 1000, 1600, 2500 Hz)
SPA	Special Purpose Average (frequencies stated by the manufacturer)
SPL	Sound Pressure Level
SPLITS	Sound Pressure Level for Inductive Telephone Simulator
STS	Simulated Telephone Sensitivity
TMFS	Telephone Magnetic Field Simulator

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